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<p>(21) International Application Number: PCT/US92/00857</p> <p>(22) International Filing Date: 12 February 1992 (12.02.92)</p> <p>(30) Priority data: 656,773 15 February 1991 (15.02.91) US</p> <p>(60) Parent Application or Grant (63) Related by Continuation US 656,773 (CIP) Filed on 15 February 1991 (15.02.91)</p> <p>(71) Applicant (for all designated States except US): UAB RESEARCH FOUNDATION [US/US]; UAB Station, Birmingham, AL 35294 (US).</p>		<p>(72) Inventors; and (75) Inventors/Applicants (for US only) : BRILES, David, E. [US/US]; 760 Linwood Road, Birmingham, AL 35222 (US). YOTHER, Janet, L. [US/US]; 2208 Heatherbrooke Road, Birmingham, AL 35242 (US). McDANIEL, Larry, S. [US/US]; 5354 Cornell Drive, Birmingham, AL 35210 (US).</p> <p>(74) Agent: DEL GIUDICE, Paul, V.; Shoemaker and Mattare, Ltd., Crystal Plaza Bldg. 1, Suite 1203, 2001 Jefferson Davis Highway, Arlington, VA 22202 (US).</p> <p>(81) Designated States: AT (European patent), AU, BE (European patent), CA, CH (European patent), DE (European patent), DK (European patent), ES (European patent), FI, FR (European patent), GB (European patent), GR (European patent), IT (European patent), JP, LU (European patent), MC (European patent), NL (European patent), NO, SE (European patent), US.</p> <p>Published <i>With international search report.</i></p>	

(54) Title: STRUCTURAL GENE OF PNEUMOCOCCAL PROTEIN

(57) Abstract

A purified pneumococcal surface protein A (PspA) comprises a truncated form of the PspA protein which is immunoprotective and contains the protective epitopes of PspA. The PspA protein is soluble in physiologic solution and lacks at least the cell membrane anchor region of the whole protein. The protein is formed by insertion-duplication of mutagenesis of *S. pneumoniae* with *pspA* gene and expression of the truncated protein into the growth medium.

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TITLE OF INVENTION
STRUCTURAL GENE OF PNEUMOCOCCAL PROTEIN

FIELD OF INVENTION

5 The present invention is concerned with the development of an improved vaccine against pneumococcal infections.

REFERENCE TO RELATED APPLICATION

10 This application is a continuation-in-part of copending United States patent application Serial No. 656,773 filed February 15, 1991.

BACKGROUND TO THE INVENTION

15 Streptococcus pneumoniae is an important cause of otitis media, meningitis, bacteremia and pneumonia. Despite the use of antibiotics and vaccines, the prevalence of pneumococcal infections has declined little over the last twenty-five years.

20 It is generally accepted that immunity to Streptococcus pneumoniae can be mediated by specific antibodies against the polysaccharide capsule of the pneumococcus. However, neonates and young children fail to make an immune response against polysaccharide antigens and can have repeated infections involving the same capsular serotype.

25 One approach to immunizing infants against a number of encapsulated bacteria is to conjugate the capsular polysaccharide antigens to protein to make them immunogenic. This approach has been successful, for example, with Haemophilus influenzae b (see U.S. Patent no. 4,496,538 to Gordon and U.S. Patent no. 4,673,574 to Anderson). However, there are over eighty known capsular serotypes of S. pneumoniae of which twenty-three account for most of the disease. For a pneumococcal polysaccharide-protein conjugate to be 30 successful, the capsular types responsible for most pneumococcal infections would have to be made adequately immunogenic. This approach may be difficult, because 35

the twenty-three polysaccharides included in the presently-available vaccine are not all adequately immunogenic, even in adults.

5 An alternative approach for protecting children, and also the elderly, from pneumococcal infection would be to identify protein antigens that could elicit protective immune responses. Such proteins may serve as a vaccine by themselves, may be used in conjunction with successful polysaccharide-protein conjugates, or as 10 carriers for polysaccharides.

In McDaniel et al (I), J.Exp.Med. 160:386-397, 1984, there is described the production of hybridoma antibodies that recognize cell surface polypeptide(s) on S. pneumoniae and protection of mice from infection with 15 certain strains of encapsulated pneumococci by such antibodies. This surface protein antigen has been termed "pneumococcal surface protein A" or PspA for short.

20 In McDaniel et al (II), Microbial Pathogenesis 1:519-531, 1986, there are described studies on the characterization of the PspA. Considerable diversity in the PspA molecule in different strains was found, as were differences in the epitopes recognized by different antibodies.

25 In McDaniel et al (III), J.Exp.Med. 165:381-394, 1987, there is disclosed that immunization of X-linked immunodeficient (XID) mice with non-encapsulated pneumococci expressing PspA, but not isogenic pneumococci lacking PspA, protects mice from subsequent fatal infection with pneumococci.

30 In McDaniel et al (IV), Infect. Immun., 59:222-228, 1991, there is described immunization of mice with a recombinant full length fragment of PspA that is able to elicit protection against pneumococcal strains of capsular types 6A and 3.

35 In Crain et al, Infect. Immun., 56:3293-3299, 1990, there is described a rabbit antiserum that detects PspA

in 100% (n = 95) of clinical and laboratory isolates of strains of S. pneumoniae. When reacted with seven monoclonal antibodies to PspA, fifty-seven S. pneumoniae isolates exhibited thirty-one different patterns of reactivity.

The PspA protein type is independent of capsular type. It would seem that genetic mutation or exchange in the environment has allowed for the development of a large pool of strains which are highly diverse with respect to capsule, PspA, and possibly other molecules with variable structures. Variability of PspA's from different strains also is evident in their molecular weights, which range from 67 to 99 kD. The observed differences are stably inherited and are not the result of protein degradation.

Immunization with a partially purified PspA from a recombinant λ gt11 clone, elicited protection against challenge with several S. pneumoniae strains representing different capsular and PspA types, as described in McDaniel et al (IV), Infect. Immun. 59:222-228, 1991. Although clones expressing PspA were constructed according to that paper, the product was insoluble and isolation from cell fragments following lysis was not possible.

While the protein is variable in structure between different pneumococcal strains, numerous cross-reactions exist between all PspA's, suggesting that sufficient common epitopes may be present to allow a single PspA or at least a small number of PspA's to elicit protection against a large number of S. pneumoniae strains.

In addition to the published literature specifically referred to above, the inventors, in conjunction with co-workers, have published further details concerning PspA's, as follows:

35 1. Abstracts of 89th Annual Meeting of the

- American Society for Microbiology, p. 125,
item D-257, May 1989;
2. Abstracts of 90th Annual Meeting of the
American Society for Microbiology, p. 98, item
D-106, May 1990;
- 5 3. Abstracts of 3rd International ASM Conference
on Streptococcal Genetics, p. 11, item 12,
June 1990;
4. Talkington et al, Infect. Immun. 59:1285-1289,
10 1991;
5. Yother et al, J. Bacteriol. 174:601-609, 1992;
and
6. Yother et al, J. Bacteriol. 174:610-618, 1992.
The latter three publications occurred after the filing
15 of the aforesaid USSN 656,773.

In the specification which follows and the drawings
accompanying the same, there are utilized certain
accepted abbreviations with respect to the amino acids
represented thereby. The following Table I identifies
20 those abbreviations:

TABLE I

AMINO ACID ABBREVIATIONS

A = Ala = Alanine	M = Met = Methionine
C = Cys = Cysteine	N = Asn = Asparagine
25 D = Asp = Aspartic Acid	P = Pro = Proline
E = Glu = Glutamic Acid	Q = Gln = Glutamine
F = Phe = Phenylalanine	R = Arg = Arginine
G = Gly = Glycine	S = Ser = Serine
H = His = Histidine	T = Thr = Threonine
30 I = Ile = Isoleucine	V = Val = Valine
K = Lys = Lysine	W = Try = Tryptophan
L = Leu = Leucine	Y = Tyr = Tyrosine

SUMMARY OF INVENTION

The present invention relates to the preparation of
35 mutants of S. pneumoniae that secrete an immunogenic
truncated form of the PspA protein, and isolation and

purification of the secreted protein. The truncated form of the PspA protein is immunoprotective and contains the protective epitopes of PspA. The PspA protein is soluble in physiologic solution and lacking 5 at least the functional cell membrane anchor region.

BRIEF DESCRIPTION OF DRAWINGS

Figure 1 is a schematic representation of the domains of the mature PspA;

10 Figure 2 is the N-terminal amino acid sequence of PspA, wherein bold upper case letters denote charged hydrophilic amino acids, lower-case letters designate apolar, hydrophobic residues, and underlined bold lower case letters denote uncharged, polar, hydrophilic residues;

15 Figure 3 is the DNA sequence of the pspA gene with deduced amino acid sequence for the PspA protein;

20 Figure 4 depicts the restriction map of pspA (Figure 4A) and the use of insertion-duplication mutagenesis to construct mutations in the pspA gene (Figure 4B),

Figure 5 shows the deduced amino acid sequence for the N-terminal region of PspA and the general location of epitopes recognized by monoclonal antibodies;

25 Figure 6 shows antibody reactivity with PspA fragments produced by various pspA gene segments; and

Figure 7 shows the mapped location of epitopes in the PspA fragments produced by the different pspA gene segments.

GENERAL DESCRIPTION OF INVENTION

30 According to one aspect of the present invention, there is provided a purified immunoprotective pneumococcal surface protein, comprising a truncated form of PspA which contains the immunoprotective epitopes of the protein and up to about 90% of the whole 35 PspA protein and from which the functional cell membrane anchor region is absent.

Through the technique of insertion-duplication mutagenesis of the pspA gene of the strain Rx1 of Streptococcus pneumoniae with plasmids containing cloned fragments of the pspA structural gene, it has 5 been possible to produce soluble fragments of PspA that are secreted by pneumococci.

In another aspect of the present invention, therefore, there is provided a method of forming an immunoprotective truncated PspA protein, which comprises 10 effecting insertion-duplication mutagenesis of a bacterium with a pspA gene resulting in the coding of a truncated expressible PspA protein, growing the mutated bacterium to effect expression of a truncated PspA protein, and isolating the protein.

15 The molecular size of the purified truncated PspA protein obtained may be varied by directing the point of insertion, which determines the termination of gene expression, to different points in the pspA gene. For example, an N-terminal fragment of apparent molecular 20 weight of 43 kD, constituting approximately one-half of the native protein, has been found useful.

25 The truncated segment which is produced by this procedure is capable of eliciting protection in mice from fatal challenge with type 3 S. pneumoniae, demonstrating for the first time that a purified PspA can elicit protection and that this truncated segment of the protein contains protective epitopes of PspA.

30 Amino acid sequence information was obtained on the N-terminal 45 amino acids of the truncated segment of PspA. This sequence is shown in Figure 2. Predictive secondary structural analysis shows that this sequence has a very strong alpha-helical formation, with no non-helical inserts. About 51% of the segment is composed 35 only of two amino acids, namely lysine, a charged amino acid, and alanine, a non-polar amino acid.

Analysis of this 45-amino acid sequence also reveals that it contains a seven-residue periodicity (see Figure 2). In PspA, the periodicity begins with residue 8 and extends throughout the entire sequence, 5 for nearly eleven turns of the helix. Positions "a" and "d" are occupied by apolar amino acids and position "b", "c" and "f" generally contain hydrophilic amino acids. Position "f" is predominantly occupied by lysine. Having regard to these observations, this region of PspA 10 is very likely in an alpha-helical coiled-coil configuration. The deduced amino acid sequence for the whole of the α -helical coiled-coil region is shown in Figure 5.

We also have cloned and sequenced the entire coding 15 region of pspA (see Figure 3). The deduced amino acid sequence for the PspA protein reveals three distinct regions of the PspA molecule, shown schematically in Figure 1. Accordingly, a further aspect of the present invention, there is provided a biologically-pure 20 recombinant DNA molecule coding for the PspA protein or portions thereof and having a coding sequence included within set forth in Figure 3 or having substantial homology thereto.

The DNA sequence of the pspA gene is contained on a 25 HindIII - KpnI fragment that is 2086 base pairs in length. The pspA gene itself represents approximately 1985 base pairs of this fragment, and comprises an initial region containing transcription and translational signals with translation starting at the 30 ATG/met (nucleotide position 127, codon position -31), followed by a leader sequence extending from the AAG/met (nucleotide position 127, codon position -31) to CGA/ala (nucleotide position 217, codon -1). Mature Pspa starts with the glu amino acid at nucleotide position 220 35 (codon +1) and ends at the translational stop TAA/OCH at

nucleotide position 1984. This translational stop codon is followed by transcription termination signals.

The amino terminal of the protein sequence, predicted from the DNA sequence of Figure 3, contains a 5 31 amino acid leader sequence and a 45 amino acid sequence identical to the 45 amino acid sequence of the N-terminal of PspA (Figure 2). The amino end of the predicted protein sequence is highly charged and α -helical in nature. This region has homology with 10 tropomyosin at the amino acid level (approximately 22% identity and 50% similarity). This homology is due largely to a repeating seven residue periodicity where the first and fourth amino acids are hydrophobic, the intervening amino acids are helix-promoting and the 15 seventh amino acid is charged. This pattern is consistent with that of an α -helical coiled-coil molecule and indicates that the α -helical coil extends through the N-terminal half of the molecule. The amino acid sequence of the whole of the α -helical coil region 20 is shown in Figure 5.

Following the charged helical region is a proline-rich region in which 23 of 81 amino acids are prolines. Immediately carboxy to the proline-rich region is the 25 first of ten highly homologous twenty amino acid repeats. The only significantly hydrophobic region in the sequenced portion of the molecule begins at the last repeat. This potential membrane-spanning region contains several charged amino acids preceding the translational stop codon.

The insertionally-inactivated mutants of 30 S.pneumoniae lacking the C-terminal anchor regions are capable of growth in chemically-defined medium and secrete the N-terminal portion of the PspA protein into the medium. The N-terminal region of PspA is highly 35 soluble in the culture medium and is much easier to isolate than the entire molecule. Soluble truncated

5 molecules have been produced using insertional duplicational mutagenesis directed by the cloned PspA DNA fragments shown in Figure 4. Expression of the same truncated construct (with the pneumococcal promoter) in E.coli results in the same PspA fragment being secreted into the periplasm of E.coli. PspA is readily released from the periplasm by hypotonic lysis.

10 Truncated PspA is isolated from culture medium of mutant pneumococci in any convenient manner, such as by tangential flow filtration. Ion-exchange chromatography then is performed on an anionic resin to purify the protein. In this procedure, the solution containing PspA is dialyzed to pH6 in 0.02 M salt solution and passed over the resin. The PspA is eluted from the 15 resin with a gradient of 0.08 to 2.0 M ionic strength and is collected in the fraction between 0.34 and 0.87 M ionic strength, depending on the nature of the column used.

20 The PspA may be further purified by sodium dodecyl sulfate polyacrylamide gel (SDS-PAGE) electrophoresis. The PspA-containing portion of the gel is identified by staining of the gel and PspA is electroeluted from this portion.

25 The electrophoresis purification is convenient when only small quantities of PspA are being handled. As an alternative, more suited to large-scale production, the protein may be purified by size chromatography in a pH7 phosphate buffer.

30 Since it is possible to obtain expression of the truncated form of PspA into the culture medium, as opposed to it being trapped within the cell wall and making purification much more complicated, it is possible to isolate other proteins that have been cloned into the truncated pspA gene by making fusion proteins 35 between PspA and other proteins. Such a technique may be employed to enhance the immunogenicity or preserve

the immunogenic structural conformation or presentation of the gene product, to permit the fusion protein to be used in immunization, which may be systemic and/or mucosal, against disease.

5 One example of such a fusion protein is a fusion of the soluble N-terminal region of PspA and the B-subunit of cholera toxin. Fusion proteins also may be formed by chemical attachment of the truncated PspA protein to other proteins.

10 Another aspect of the present invention, therefore, provides a method for the production of cloned proteins, which comprises fusing a *pspA* gene coding for a truncated form of PspA protein with the gene coding for another protein to form a fusion protein clone, 15 transforming *S.pneumoniae*, *E.coli* or other bacteria with the fusion protein clone, growing the transformed bacterium to effect expression of a fusion protein comprising truncated PspA and the other protein into the culture medium, and isolating the fusion protein.

20 By using this technique, there can be produced cloned proteins in gram positive bacteria, such as pneumococci, for example, *S.pneumoniae*, and mycobacteria, for example, Bacille Calmette-Guerin (BCG). This approach overcomes the problems inherent in 25 the production of proteins in gram negative bacteria, such as *E. coli*, usually used for cloning, in particular the need to purify the recombinant proteins from endotoxin and the toxicity of many gram positive DNA sequences in gram negative organisms.

30 For the expression of a fusion protein comprising the soluble N-terminal region of PspA and the B-subunit of cholera toxin (CTB), a gene fusion of a *pspA* gene coding for a truncated form of PspA protein with a *ctxB* gene coding for the B-subunit of cholera toxin is 35 effected. Following expression of the fusion protein, the PspA and CTB may be cleaved one from another by

dilute acid at an asparagine-proline sequence, known to be labile to dilute acid, engineered at the fusion site of the two proteins.

CTB is known to be highly specific for 5 monosialoganglioside (GM₁). Accordingly, the fusion PspA-CTB protein may be isolated from the culture medium by adsorption to a GM₁ affinity column, from which the fusion protein subsequently may be eluted at low pH.

The PspA-CTB fusion protein finds considerable 10 utility in solid phase immunoadsorbant assays. By using the fusion protein, it is possible to coat solid supports, such as microtitration plates, with PspA fragments without having first to isolate the PspA fragments. This may be done by adding bacterial extract 15 containing the fusion protein to plates coated with GM₁. The PspA-CTB fusion protein then binds to GM₁ through the CTB moiety, thereby coating the solid support with PspA. The resulting coated product then may be used in a solid phase immunoadsorbant assay for the detection of 20 PspA antibody and/or antigen in test samples. Such immunoadsorbant assays constitute an additional aspect of this invention.

The PspA attachment/anchor region, containing the proline-rich region, the repeat region and/or the C-terminus of PspA, also may be employed to effect 25 expression of heterologous proteins in pneumococci, or other gram positive or gram negative bacteria in the which the attachment/anchor region is functional. Generally, expression is effected on bacterial membrane, 30 cell walls or cell surfaces in gram positive bacteria and in the periplasm of gram negative bacteria. An example of such heterologous protein is the B-subunit of cholera toxin.

As mentioned above, the truncated form of PspA 35 provided herein contains the immunoprotective epitopes of the protein and hence is useful in a vaccine against

pneumococcal infection. Accordingly, a yet further aspect of the present invention provides a vaccine against pneumococcal infection comprising, as an immunogenically-active component, the purified immunoprotective pneumococcal surface protein provided herein. The PspA protein may be employed as one component of a multicomponent vaccine which is effective in providing protection from a variety of infections.

10 In addition, gram positive bacteria which have been transformed to express the pspA gene coding for the truncated soluble PspA protein may be employed, in a live-attenuated or killed form, as an immunologically-active component of a vaccine against pneumococcal infection. In the transformed bacterium, such pspA gene may be fused to a gene coding for another protein. Accordingly, an additional aspect of this invention provides a vaccine against pneumococcal infection comprising, as an immunologically-active component, a live-attenuated or killed bacteria containing a gene coding for the truncated form of PspA.

25 The truncated form of PspA also may be employed in conjugates with normally weakly-immunogenic or non-immunogenic protection-eliciting molecules, such as various polysaccharides, to achieve immunogenic potentiation thereof. An additional aspect of the invention, therefore, provides a vaccine comprising, as an immunogenically-active component, a conjugate of the purified immunoprotective pneumococcal surface protein provided herein and a normally weakly-immunogenic or non-immunogenic protection-eliciting molecule.

30 35 Conserved sequences of pspA, particularly those in the proline-rich and/or repeat regions of the gene, may be employed as probes to detect the presence of pneumococci of various strains, through detection of pneumococcal DNA, in tissues, body fluids and/or

secretions. Similarly, portions of the pspA gene may be used in diagnostic kits for the detection of pneumococcal infections.

In addition, primers made based on conserved 5 sequences of pspA, particularly those in the proline-rich and/or repeat regions, may be used to assay for the presence of pneumococci in tissues, body fluids and/or secretions, through amplification of pneumococcal DNA. In this regard, a single primer pair derived from the 10 nucleotide sequence of the pspA gene of S.pneumoniae may be employed in an assay using the polymerase chain reaction (PCR) for the specific detection of Streptococcus pneumoniae.

Specific amplification has been achieved of a 678 15 base pair DNA fragment from S.pneumoniae strain Rx1. After 30 cycles of amplification, the amplier was detectable by agarose gel electrophoresis. The fragment was successfully amplified in all 32 strains of S.pneumoniae tested. PCR DNA amplification was able to 20 detect less than an estimated 20 picograms total genomic pneumococcal DNA.

Primers LSM1 and LSM2, having the nucleotide sequences:

LSM1 5'-CCGGATCCAGCTCCTGCACCAAAAC-3'

25 LSM2 5'-GCGCTGCGACGGCTTAAACCCATTCAACCATTGG-3'

amplified the 678 base pair product from pspA from nucleotides 1312 to 1990 of the Rx1 pspA sequence (Figure 3).

The PCR analysis using the primers described herein 30 is performed in accordance with conventional PCR techniques, such as are described in the literature, for example, as described in Arnhem et al at C&EN Special Report, 36, October 1, 1990. For detection purposes, the primer may be labelled or labelled nucleotide 35 triphosphates may be included in the PCR reaction to label the PCR amplification product.

The PCR primers may be prepared by well-known methods, for example, by oligonucleotide synthesis or by fragmentation of a larger nucleotide sequence using suitable restriction enzymes.

5 The ability to use a single primer capable of detecting a large number of S.pneumoniae strains enables a universal PCR detection kit to be provided which is able to diagnose pneumococcal infection in mammals, including humans, independent of the strain
10 which has caused the disease.

STRAINS, PLASMIDS AND PROBES

In the Examples which follow as well as in the accompanying drawings, reference is made to certain plasmids and bacterial strains transformed by such
15 plasmids as well as vector DNA segments, some of which have been deposited with ATCC and all of which are fully described herein. The following Table II provides a summary of such materials.

<u>Identification</u>	<u>Type</u>	<u>Description</u>	<u>Deposit</u>	<u>Location</u>
JY4313	<u>E.coli</u> strain	PspA DNA	ATCC 68529	Fig. 1
JY2008	<u>S.pneumoniae</u> strain	PspA fragment 43 kDa	ATCC 55143	Fig. 1
JY4306	<u>E.coli</u> strain	PspA fragment 43 kDa	ATCC 68522	Fig. 3
JY4310		PspA fragment 21 kDa	None	Fig. 7
JY4285		PspA fragment 18 kDa	None	Fig. 7
JY4163	Plasmid	Expression plasmid used for expression of PspA -CTB fusion protein (29 kDa)	None	Fig. 6
JY4323	DNA probe	HindIII-KpaI segment	None	Fig. 9
JY4306	DNA probe	HindIII-Dra-I segment	None	Fig. 9
JY4262	DNA probe	BclI-Bst-NI segment	None	Fig. 9

EXAMPLESExample 1

This Example illustrates the preparation and growth of novel strains of *S. pneumoniae*.

5 The *S. pneumoniae* strain Rx1, which is a non-encapsulated derivative of capsular type 2 strain D39 (National Collection of Type Cultures, London, NCTC #7466), was subjected to insertional inactivation (as described in McDaniel et al (III) 1987, Crain et al 10 1990, Talkington et al 1991, with 10 different cloned fragments of PspA (see Figure 4). These fragments have all been obtained from restriction digests of cloned PspA DNA on a plasmid in *E.coli* strain JY4313 (deposited with the American Type Culture Collection on January 31, 15 1991 under ATCC accession number 68529). This insertional duplication mutagenesis (see Figure 4) results in the termination of gene expression near the 3' end of the cloned fragment.

20 One of the resultant strains, JY2008 (deposited with the American Type Culture Collection on January 24, 1991 under accession number 55143), which was produced by a fragment of DNA encoded in pKSD300 (McDaniel et al (III) 1987), produces a PspA fragment of 27 kDa (apparent molecular weight 43 kDa). This fragment is 25 approximately 40% the size of the native 65 kDa (84 kDa apparent size) protein.

30 The expected molecular size is based on the deduced amino acid sequence and the apparent molecular size is based on migration in SDS-PAGE. The difference between expected and apparent molecular size is due to the conformation of the PspA fragment.

35 The proline and repeats/anchor regions (see Figure 1) were deleted and the resulting protein was unable to attach to cell due to their absence. The unattached protein then may be isolated from culture supernatants, as described below.

By directing the insertion to different points in the *pspA* gene, different lengths of truncated, non-

attached PspA protein derivatives can be produced, as seen in Figure 7.

The pneumococcal strain JY2008 was grown in 6 liters of a chemically defined medium (see Inf. Imm. 27:444) 5 supplemented with 0.10% choline chloride, 0.075% L-cysteine hydrochloride and 0.25% NaHCO₃. The supernatant fluid of the mid-log phase culture of JY2008 was harvested using a 0.22 μ m membrane tangential flow filter and concentrated 60 fold.

10 Introduction of the plasmid pKSD300 into the unmodified D39 strain similarly yielded the 43 kD truncated PspA protein. Introduction of the plasmid pKSD300 into the type 3 *S.pneumoniae* strain WU2 (PspA protein approximately 92 kD) yielded, upon growth of the 15 organism, a non-attached truncated PspA protein of approximately 46 kD molecule size.

Example 2

This Example illustrates the purification of PspA.

20 The concentrated supernatant fluid, produced as described in Example 1, was washed in 0.1 M PBS, pH 7.2, and ultracentrifuged at 196,000 xg. The supernatant fluid was diluted 1:5 in 20 mM L-histidine buffer-NaCl, the pH adjusted to 6.0 and the injected into a DEAE-fibered Isonet-D2 an ion exchange column.

25 A stepwise NaCl gradient from 80 mM to 2 M was applied to the column and PspA-containing fractions (0.32 to 0.64 M ionic strength) were pooled and separated on an SDA-polyacrylamide gel. The proteins on a representative section of the gel were stained with Comassie Blue R-250 to identify PspA. The fraction containing PspA was excised from the remainder of the SDS-gel and electroeluted from the excised gel. The eluted protein was precipitated in a 50:50 methanol:acetone solvent and resuspended in PBS. Purity 30 of product was confirmed by silver staining and Western Immunoblotting with mAb X1126 (IgG 2b, k, see McDaniel et al (I), supra).

Example 3

This Example illustrates the isolation of PspA from the periplasmic space of Escherichia coli.

Isolation from the periplasmic space of E. coli was 5 accomplished by standard techniques. E. coli strain JY4306 (which produces the 43 kDa N-terminal fragment of PspA, the amino acid sequence of which is shown in Figure 3. This strain was deposited with ATCC on January 31, 1991 under accession number 68522) was 10 washed in buffered saline, incubated in 20% sucrose, 10 mM EDTA, 25 mM Tris pH 7.7 for 10 minutes at 0°C. The cells then were spun at 400 xg for 10 minutes at 0°C. All supernatant was removed from the pellet and the pellet was resuspended rapidly in about 100 volumes of 15 4°C water. After 10 minutes the suspension was centrifuged at 4,000 xg for 10 minutes at 4°C. The pellet was discarded and the supernatant, which contained the PspA was saved. Concentration of the supernatant was by standard procedures such as 20 concentration against solid sucrose or ultrafiltration. Purification of the protein isolated from E. coli proceeded by the same chromatography techniques used for the isolated of the 43 kDa (truncated) PspA from the media of growing pneumococci.

25 Example 4

This Example illustrates the immunogenic properties of the PspA protein.

Sixteen 7-week old CBA/N mice carrying the Xid 30 mutation (Jackson Laboratories, Bar Harber, ME) were bled via the periorbital sinus to establish pre-exposure levels of antibody to PspA. Purified PspA, prepared as described in Example 2, was emulsified in complete Freund's adjuvant and injected subcutaneously into the inguinal and axillary regions, delivering approximately 35 5 µg of protein per mouse. Fourteen days later, the mice were injected intraperitoneally with 5 µg of PspA,

prepared as described in Example 2. Control mice were immunized via the same routes with sterile SDS buffer. Seven days after the last immunization, all mice were bled via the periorbital sinus and were challenged 5 intravenously with 300 CFU of the type 3 strain WU2, grown as described in Example 1.

Preimmunization and prechallenge sera were analyzed by Western immunoblots to establish baseline and postimmunization response to the truncated protein. The 10 PspA of strain WU2 was electrophoresed and transferred to nitrocellulose membranes. The membranes were separated into strips and probed with the appropriate mouse antisera at a 1:50 dilution for 2 hours, incubated with biotinylated goat anti-mouse immunoglobulin for 1 15 hr, washed and incubated with Streptavidin-conjugated phosphatase. The membranes were developed with 5-bromo-4-chloro-3-indoyl phosphate toluidine salt with 0.01% into blue tetrazolium.

Of the eight CBA/N mice immunized with the purified 20 fragment of PspA, all were still alive 14 days after challenge with strain WU2 and none showed any signs of illness following challenge. Of the eight mice immunized with buffer controls, six were dead by two days post challenge, while the two remaining control 25 mice appeared very sick, with ruffled fur, arched back and decreased movement, two to three days following challenge but survived. Chi-square analysis indicated that there was a significant difference ($P < 0.003$) in survival between the immunized and control groups.

30 Preimmunization and prechallenge sera were analyzed by Western immunoblotting. None of the preimmunization sera contained antibody to truncated PspA. Postimmunization sera from eight of eight mice contained detectable antibodies to PspA, and six mice had very 35 strong anti-PspA reactions. When the challenge strain WU2 was probed with the antisera, all the immunized mice

had antibodies that were highly cross-reactive with the WU2 PspA epitopes. No control mice developed antibodies to PspA.

5 The immunization data is summarized in the following Table III:

Table III

	Immunogen	Detection of Antibody to PspA	Alive at 2 days post challenge	Alive at 14 days post challenge
10	Isolated PspA (Example 2)	8/8	8/8	8/8
	Sterile SDS (control)	0/8	2/8	2/8

15 As may be seen from the data in Table III, immunization with two 5 μ g doses of the purified PspA molecule elicited protection against fatal infection of CBA/N mice and elicited antibodies reactive with the PspA of the challenge strain.

20 Example 5

This Example illustrates sequencing of the PspA protein.

Purified PspA, prepared as described in Example 2, was electrophoresed through 9% resolving gels 25 containing recrystallized SDS with the Laemmli buffer system (Nature 227:680). The gels were soaked twice in a 10mM 3-(cyclohexylamino)-1-propanesulfonic acid, pH 11.0, containing 10% methanol for 10 minutes. A polyvinylidene difluoride membrane (PVDF) was wetted 30 completely for several seconds in 100% methanol, then washed in CAPS buffer for 10 min. PspA was electrotransferred to the PVDF membrane in CAPS buffer at 0.5 A for 1 hr. After transfer, the membrane was washed two times in deionized water for 5 min, and 35 stained with 0.1% Coomassie Blue R-250 in 50% methanol for 20 minutes. The section of the membrane containing PspA was excised and destained in 40% methanol and 10% acetic acid for 5 min. The membrane was cut into small

segments and stored in sterile Eppendorf tubes until sequencing.

The isolated PspA was sequenced directly from the PVDF membranes. Figure 2 depicts the N-terminal 45 residue amino acid sequence and Figure 5 depicts the amino acid sequence for the whole alpha-helical region. The DNA sequence of the whole pspA gene and the deduced amino acid sequence for the PspA protein are shown in Figure 3.

10 Example 6

This Example illustrates the use of the pspA 5'-sequence and/or the PspA N-terminal region to serve as an expression and leader sequence for expressing and/or excreting/secretting heterologous proteins from S.pneumoniae and E.coli. In this Example, there is described the expression of the N-terminal of the PspA protein fused to the B-subunit of cholera toxin (CTB) through a genetic fusion and the excretion of the fused protein from pneumococci and its secretion into the periplasmic space of E.coli.

A fusion protein consisting of CTB and the N-terminal half of PspA was constructed and expressed in E.coli. The HindIII/DraI pspA gene fragment used contained all the pspA transcription and translation initiation signals and the PspA signal peptide leader sequence for transport across the cell membrane. The mature PspA encoded by this fragment is predicted to be a product of 29 kDa (observed molecular weight of 42 kDa), encompassing more than 90% of the α -helical coiled-coil domain. The CTB fragment used lacked transcription and translation initiation signals. Expression from pspA promoter through pspA and then in-frame translational readthrough into the CTB-encoding gene ctxB resulted in production of a 12 kDa CTB product fused to the upstream PspA product. The PspA-CTB fusion protein was stably expressed in both high and low copy

number plasmids (pUC18, more than 100 copies/cell; pJY4163, about 15 to 30 copies/cell) in E.coli.

5 The fusion products were of the expected size (about 54 kDa) and reacted with antibody to both PspA and CTB. That the CTB product retained its functionality was demonstrated by the ability of the fusion protein to bind ganglioside GM1, a property of CTB.

10 The high level of expression of the fusion product apparently resulted in a reduced rate of processing and/or conformational changes that prevented the protein from being completely transported to the periplasm. However, in the lower copy number construct, about 60% of the fusion protein was localized in the periplasm, 15 where large quantities were readily released from E. coli by osmotic shock.

20 In addition to expression in E.coli, the fusion protein also was expressed in S.pneumoniae by transformation of the low copy number construct into the avirulent S.pneumoniae Rx1 to generate an insertion-duplication mutant. In this way, the gene encoding the fusion protein was integrated into the S.pneumoniae chromosome, from which it was stably expressed. As in 25 the case of Example 1, the truncated PspA molecule lacking the attachment/anchor region, this time in the form of the PspA-CTB fusion protein, was excreted into the culture supernatant. The fusion protein product was of the expected molecular size (54 kDa), reacted with antibody to PspA and CTB, and bound GM1.

30 Example 7

35 This Example illustrates the use of PspA attachment or anchor region to permit expression of heterologous proteins on the surface of S.pneumoniae or other bacteria in which the attachment/anchor sequence is functional in particular the expression of a PspA-CTB

(cholera toxin B subunit) fusion expressed on the surface of pneumococci.

The N-terminal encoding region of PspA, including its transcription and translation initiation signals and its signal peptide leader sequence, is linked via a translationally in-frame genetic fusion to the CTB-encoding ctxB fragment that lacks transcription and translation initiation and termination signals. This sequence is followed in-frame by the PspA attachment/anchor domain, including part or all of the proline, repeat and C-terminal domains. The resulting fusion protein is directed to the outside of the cell via the PspA leader sequence, which is cleaved following transport across the membrane, and then attached to cell by the PspA attachment/anchor sequence. The heterologous protein, located between the two PspA fragments is expressed on the outside surface of the membrane and, in S.pneumoniae, on the surface of the cell.

20 Example 8

This Example illustrates the expression of truncated and full length PspA by the Mycobacterium tuberculosis strain Bacille Calmette-Guerin (BCG).

BCG was chromosomically modified to incorporate the pspA gene coding for the truncated PspA protein. The 43 kDa truncated PspA protein was expressed from the modified BCG to approximately 15% of total BCG protein. This result was achieved with an expression vector construct carrying the pspA gene segment encoding the 43 kDa region without its 5'-secretion signal. Expression was only about 1% of BCG protein when the PspA or mycobacterial signal sequences were included. In either case, a significant portion of the expressed PspA was excreted into the medium. Expression of the 43 kDa PspA protein in a fusion with the mycobacterial lipoprotein

signal sequence resulted in the expression of the recombinant PspA in the membrane fraction of BCG.

This latter result suggested that the fusion of the lipoprotein signal sequence resulted in acylation of the recombinant PspA. Fluorescent activated cell sorting with fluorochrome-conjugated monoclonal antibodies to PspA demonstrated expression of PspA on the surface of these bacteria.

Example 9

10 This Example illustrates the close homology of portions of the pspA gene among different strains of pneumococci and the potential that such homology may be useful for molecular (DNA) approaches to detect pneumococci in tissues, body fluids and/or secretions 15 and to identify pneumococci grown from patient samples.

Three DNA probes were employed, namely full length pspA, JY4323 (N-terminal HindIII to C-terminal KpnI), the N-terminal half of pspA, JY4306 (N-terminal HindIII to DraI at position 996 (see Figure 3) and most of the 20 proline and repeat regions, JY4262 (BclII at position 1221 to BstNI at position 1832). Under stringency conditions requiring 95% identity, probes JY4323 and JY4262 reacted with cells of over 200 independent isolates of S.pneumoniae by Southern blot.

25 When the chromosomal DNA was cut with HindIII, there generally was observed that each of these probes detected two discrete bands whose exact size was dependent on the strain examined. In Rx1 pneumococci, the two bands were 4.0 and 9.1 kb. The 4.0 kb band 30 corresponded to pspA and was altered or absent in pspA mutants. The other band shares some homology with the coding regions for both the N-terminal and C-terminal halves of PspA but is not affected by pspA mutations. The JY4323 and JY4262 probes failed to react with 35 another gram positive bacterium, Streptococcus pyogenes, and a gram negative bacterium, Salmonella typhimurium.

The N-terminal probe, JY4306, recognized about one-third of the strains of pneumococci tested.

These results indicate that a sequence included in the proline/repeat region is shared by all strains of pneumococci and apparently not by other bacterial species. Sequences in the N-terminal half of the molecule appear to be more variable.

Example 10

10 This Example illustrates the detection and determination of the location of epitopes in the α -helical N-terminal region of PspA.

15 Monoclonal antibodies protective against pneumococcal infection in a mouse model, denoted by an asterisk in Figures 5, 6 and 7, were used to determine the location of epitopes for each antibody in the α -helical N-terminal region of PspA. The sites were mapped to fragments of PspA. The results are illustrated in Figures 5 to 7, with Figure 5 showing the deduced amino acid sequence for the N-terminal region of 20 PspA and the general location of epitopes recognized by monoclonal antibodies, Figure 6 showing antibody reactivity with PspA fragments produced by various pspA gene segments, and Figure 7 showing the mapped location of epitopes in the PspA fragments produced by the 25 different pspA gene segments.

Numbers 138, 193 and 261 in Figure 5 indicate break positions in the PspA fragments used to map the location of epitopes detected by monoclonal antibodies Xi1526, Xi126, XiR35, XiR38, XiR1224, XiR16, Xi64, 30 XiR278, Xi1325 and Xi1323. The asterisk (*) after some of the antibodies denotes those which are able to protect against fatal pneumococcal infection with strain WU2 pneumococci.

35 In addition, the vertical lines to the right of the Figure indicate those areas predicted to have coiled-coil α -helical structure. The divisions to the left of

the Figure indicate the mapped location of the epitopes for each antibody.

SUMMARY OF DISCLOSURE

In summary of this disclosure, the present invention relates to a truncated PspA molecule capable of eliciting an immunoprotective response and hence containing the protective epitopes of PspA protein. Modifications are possible within the scope of this invention.

CLAIMS

What we claim is:

1. A purified immunoprotective pneumococcal surface protein (PspA), comprising a truncated form of PspA which contains the immunoprotective epitopes of the protein and up to about 90% of the whole PspA protein and from which the functional cell membrane anchor region is absent.
2. The protein of claim 1 containing approximately 50% of the whole PspA protein from which the cell membrane anchor region, the repeat region and the proline region are absent.
3. The protein of claim 1 comprising at least the N-terminal, protective epitope-containing region of the PspA protein.
4. The protein of claim 1 comprising at least the N-terminal, protective epitope-containing region of the PspA protein having the domains shown in Figure 1.
5. The protein of claim 1 comprising an N-terminal α -helical coil region of the whole PspA protein.
6. The protein of claim 5 wherein said α -helical coil region has a seven residue periodicity.
7. The protein of claim 1 comprising the 43 kD (apparent molecular size) N-terminal region of an 84 kD PspA protein.
8. A biologically-pure recombinant DNA molecule coding for at least a portion of the PspA protein and having a coding sequence included in that set forth in Figure 3 or having substantial homology thereto.
9. The DNA molecule of claim 8 coding for at least part of an α -helical coiled coil region of the PspA protein.
10. The DNA molecule of claim 8 coding for at least part of a proline rich region of the PspA protein.
11. The DNA molecule of claim 8 coding for at least part of a repeat region of the PspA protein.

12. A biologically-pure recombinant DNA molecule coding for a truncated form of the PspA protein which contains the immunoprotective epitopes of the protein and contains up to about 90% of the whole PspA protein from which the cell membrane anchor region is absent, said DNA molecule having a coding sequence included in that set forth in Figure 3 or having substantial homology thereto.
13. The DNA molecule of claim 12 which codes for a truncated form of the PspA protein which contains approximately 50% of the whole PspA protein from which the cell membrane anchor region, the repeats region and the proline region are absent.
14. The DNA molecule of claim 12 which is linked by a translationally in-frame genetic fusion to a gene coding for another protein.
15. The DNA molecule of claim 14 wherein said gene coding for another protein is a ctxB gene.
16. A method of forming an immunoprotective truncated PspA protein, which comprises:
 - effecting insertion-duplication mutagenesis of a bacterium with a pspA gene resulting in the coding of a truncated expressible PspA protein,
 - growing said mutated bacterium to effect expression of a truncated PspA protein, and
 - isolating said protein.
17. The method of claim 16 wherein said bacterium comprises an S.pneumoniae strain, said mutated strain is grown in a defined medium to effect expression of the truncated PspA protein into said medium, and the protein is isolated from the medium.
18. The method of claim 17 wherein said mutated strain is S.pneumoniae strain JY2008.
19. The method of claim 16 wherein said bacterium comprises an E.coli strain, said mutated strain is grown in a defined medium to effect expression of the

truncated PspA protein into the periplasm of said mutated strain, and the truncated protein is isolated from the periplasm of said mutated strain.

20. The method of claim 19 wherein said mutated strain is E.coli strain JY4306.

21. The method of claim 16 wherein said bacterium comprises a Mycobacteria strain.

22. The method of claim 21 wherein said mutated strain is mutated BCG.

23. The method of claim 16 wherein said isolated protein is purified by ion-exchange chromatography.

24. A mutated strain of Streptococcus pneumoniae comprising a pspA gene coding for a truncated expressible PspA protein.

25. The strain of claim 24 which is the JY2008 strain of S.pneumoniae.

26. The strain of claim 24 which is the JY4310 strain of S.pneumoniae.

27. The strain of claim 24 which is the JY4285 strain of S.pneumoniae.

28. The strain of claim 24 possessing a pspA gene coding for a truncated PspA protein linked to a gene coding for another protein.

29. The strain of claim 28 wherein said gene coding for another protein is the ctxB gene coding for the B-subunit of cholera toxin.

30. The strain of claim 29 which is the JY2182 strain of S.pneumoniae.

31. A mutated strain of Mycobacterium comprising a pspA gene coding for a truncated expressible PspA protein.

32. The strain of claim 31 which is mutated BCG.

33. A mutated strain of Eschericia coli possessing a pspA gene coding for a truncated expressible PspA protein.

34. The strain of claim 33 which is the JY4306 strain of E. coli.

35. The strain of claim 33 which is the JY4353 strain of E. coli.

36. A method for the production of cloned proteins which comprises:

fusing a pspA gene coding for a truncated form of PspA protein with the gene coding for another protein to form a fusion protein clone,

transforming a bacterium with said fusion protein clone,

growing the transformed bacterium to effect expression of a fusion protein comprising truncated PspA and said other protein, and

isolating said fusion protein.

37. The method of claim 36 wherein said bacterium is a gram positive bacterium, the transformed gram positive bacterium is grown in a defined medium to effect expression of the fusion protein into said medium, and the fusion protein is isolated from the medium.

38. The method of claim 37 wherein said gram positive bacterium is a strain of S. pneumoniae.

39. The method of claim 37 wherein said gram positive bacterium is a strain of Mycobacterium.

40. The method of claim 36 wherein said bacterium is a gram negative bacterium, the transformed gram negative bacterium is grown in a defined medium to effect expression of the fusion protein into the periplasm of said bacterium, and the fusion protein is isolated from said periplasm.

41. The method of claim 40 wherein said gram negative bacterium is a strain of E. coli.

42. The method of claim 36 wherein said gene coding for another protein is a gene coding for the B-subunit of cholera toxin (CTB).

43. The method of claim 42 wherein said fusion protein comprises an acid labile sequence joining said truncated form of PspA protein and CTB and said PspA protein and CTB are separated from each other by dilute acid treatment.

44. The method of claim 42 wherein said fusion protein is isolated from culture medium by adsorption to a GM1 affinity column, from which said fusion protein is eluted.

45. A vaccine against pneumococcal infection, comprising, as an immunogenically-active component, the protein defined in claim 1.

46. The vaccine of claim 45 wherein said protein is conjugated to a normally weakly-immunogenic or non-immunogenic protection-eliciting molecule.

47. A vaccine against pneumococcal infection, comprising, as an immunologically activated component, a live-attenuated or killed gram positive bacteria containing a gene coding for the protein defined in claim 1.

48. The vaccine of claim 47 wherein said gram positive bacteria is Streptococcus pneumoniae.

49. The vaccine of claim 47 wherein said gram positive bacteria is Mycobacterium tuberculosis.

50. A DNA probe for the detection of pneumococcal DNA in a sample, comprising a conserved sequence of the pspA gene.

51. The DNA probe of claim 50 wherein said conserved sequence is located in the proline-rich region of the gene, the repeat region of the gene or both.

52. The DNA probe JY4262.

53. The DNA probe JY4323.

54. A DNA primer for effecting polymerase chain reaction of pneumococcal DNA comprising a conserved sequence of the pspA gene for assaying a sample for the presence of pneumococci.

55. The DNA primer of claim 54 wherein said conserved sequence is located in the proline-rich region of the gene, the repeat region of the gene or both.

56. The DNA primer of claim 55 wherein said conserved sequence comprises a 678 base pair fragment of S. pneumoniae strain Rx1 extending from nucleotide 1312 to 1990 of the pspA sequence of Figure 3.

57. The DNA primer of claim 55 wherein said primer has the nucleotide sequence:

5'-CCGGATCCAGCTCCTGCACCAAAAC-3' (LSM1)

or

5'-GCGCTGCGACGGCTTAAACCCATTCAACCATTGG-3' (LSM2)

58. In a solid phase immunoabsorbant assay, the improvement which comprises a coating of a truncated form of PspA protein on a solid substrate wherein said PspA protein is fused to the B-subunit of cholera toxin (CTB) which is bound to monosialoganglioside (GM1) coating said solid substrate.

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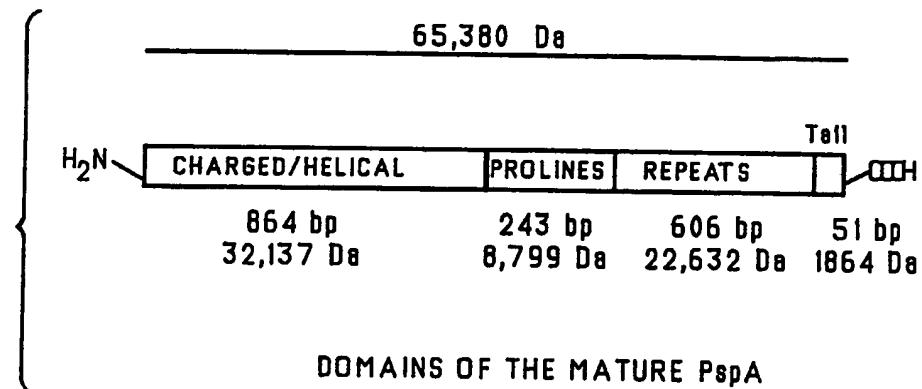


FIG. 1.

FIG.2.
SUBSTITUTE SHEET

FIG. 38.

Dna sequence		→ 1-phase Translation		amino acid 2086 b.p. AAGCTTATGATA . . . TCTTTAGGTAC		Linear	
1	/						
AAG	CCT	ATG	ATA	TAG	AAA	TTT	GTA
61	/	21					
CGG	AGG	AGG	CTT	ATA	CCT	AAT	ATA
121	/	41					
ATT	TAG	ATG	AAT	AAG	AAA	ATG	ATT
181	/	61	met	lys	lys	lys	leu
GCT	GGT	TTT	GCG	TCT	CAG	CCT	ACT
81	gly	phe	val	ala	ser	glu	thr
241	/	81					
CAG	TCT	AAA	GCT	GA6	AAA	GAC	TAT
glu	ser	lys	ala	glu	lys	asp	tyr
301	/	101					
GCA	6TA	GAA	GAT	6CT	CAA	AAG	GCT
81	val	glu	asp	ala	glu	lys	lys
361	/	121					
GAG	GAT	CAG	AAG	ACT	GAG	GAG	AAA
glu	asp	glu	lys	lys	lys	lys	lys
421	/	141					
GAT	AA6	GCA	GCA	6TT	CAA	GCA	GCG
81	lys	ala	val	ala	val	glu	lys
481	/	161					
GCC	GCA	AAA	GAC	6CA	GAT	AAG	ATG
81	81	lys	asp	ala	lys	lys	lys
541	/	181					
AAA	ACT	AAA	TTT	AAT	ACT	GTT	GCA
lys	thr	lys	phe	asn	thr	lys	lys
601	/	201					
ACT	AAG	AAA	AAA	TCA	GAA	GAA	GCT
thr	lys	lys	lys	ser	glu	lys	glu

FIG. 3b.

661	/	221	GAA	GCT	AAA	GCA	AAA	TTA	GAA	GAG	GCT	GAG	AAA	GAA	AAA	TTA	GAA	GCC	AAA	CAA	AAA	TTG
glu	glu	lys	glu	lys	lys	lys	lys	leu	glu	glu	glu	lys	lys	lys	lys	lys	glu	lys	lys	lys	lys	lys
721	/	241	GAT	GCT	GAA	GAA	GTC	CCT	CAA	GCT	AAA	ATC	GAA	TTC	GAA	AAT	CAA	GTT	CAT	AGA	lys	lys
asp	glu	glu	val	glu	val	glu	glu	pro	glu	glu	lys	lys	lys	lys	lys	glu	glu	lys	lys	lys	lys	
781	/	261	CTA	GAA	CAA	GAG	CTC	AAA	GAG	ATT	GAT	GAG	TCT	GAA	TCA	CAT	TAT	GCT	AAA	GAA	GGT	
lys	glu	glu	glu	lys	lys	lys	lys	lys	lys	asp	glu	lys	lys	lys	lys	asp	lys	lys	lys	lys	lys	
841	/	281	TTC	CCT	GCT	CTT	CAA	TCT	AAA	TTG	GAT	GCG	AAA	GCT	AAA	GCT	AAA	CTA	AAA	CTT	6AA	
phe	arg	glu	glu	glu	lys																	
901	/	301	CAG	TTA	AGT	GAT	AAG	ATT	GAT	GAG	TTA	GAC	GCT	GAA	ATT	GCA	AAA	CTT	GAA	GAT	CTT	
glu	leu	lys	asp	lys																		
961	/	321	AAA	GCT	GCT	GAA	GAA	AAC	AAT	AAT	GTA	GAA	GAC	TAC	TTC	AAA	GAA	GGT	TTC	GAA	ACT	
lys	glu	glu	glu	glu	glu	lys																
1021	/	341	ATT	GCT	AAA	AAA	GCT	GAA	TTA	GAA	AAA	ACT	GAA	GCT	GAC	CTT	AAG	AAA	GCA	GTT	AAT	
lys	glu	lys																				
1081	/	361	GAG	CCA	GAA	AAA	CCA	GCT	CCA	GAA	ACT	CCA	GCC	TTC	TTC	AAA	GAA	CCA	GCT	GAA	CCA	
glu	pro	lys																				
1141	/	381	CCA	AAA	CCA	GCA	CCG	GCT	CCA	GCT	CAA	GAT	CAA	CCT	GAA	AAA	CCA	GAG	AAG	CCA	GCT	
glu	lys																					
1201	/	401	CCA	AAA	CCA	CAA	AAA	ACA	GAT	GAT	CAA	CAA	CAA	CCG	CCA	AA	CTT	CAA	AAA	CCA	GCT	
glu	lys																					
1261	/	421	GAA	GAA	GAA	TAT	AAT	GGC	TTG	ACT	CAA	CAG	CAG	CCT	GAA	GAA	GAC	TAT	GCT	CCT	TCA	
lys	glu	glu	tyr	lys																		
1321	/	441	GCA	CCA	CCA	ACA	GGC	TGG	AAA	CAA	GAA	AAC	GGT	ATG	TGG	TAC	TTC	ATC	ACT	GAT	GGT	
lys	lys	lys	thr	glu	lys																	

1381	/	461	ATG	GGG	GGG	TGG	CTC	CAA	AAC	AAC	AAC	CTC	TAC	TGG	/	471
	met	881	ACA	ACA	ACA	trp										
1441	/	481	ATG	GGT	GGT	TGG	CTC	CAA	TAC	AAT	GGT	TCA	TAC	TAC	TAC	TAC
	met	881	ACA	ACA	ACA	trp										
1501	/	501	ATG	GGT	GGT	TGG	CTC	AAA	GTC	AAC	GGT	TCA	TAC	TAC	TAC	TAC
	met	881	ACA	ACA	ACA	trp										
1561	/	521	ATG	GGT	GGT	TGG	CTC	CAA	TAC	AAC	GGT	TCA	TAC	TAC	TAC	TAC
	met	881	ACA	ACA	ACA	trp										
1621	/	541	ATG	GGT	GGT	TGG	CTC	CAA	TAC	AAC	GGT	TCA	TAC	TAC	TAC	TAC
	met	881	ACA	ACA	ACA	trp										
1681	/	561	ATG	GGT	GGT	TGG	CTC	AAA	GTC	AAC	GGT	TCA	TAC	TAC	TAC	TAC
	met	881	ACA	ACA	ACA	trp										
1741	/	581	ATG	GGT	GGT	TGG	CTC	CAA	TAC	AAC	GGT	TCA	TAC	TAC	TAC	TAC
	met	881	ACA	ACA	ACA	trp										
1801	/	601	ATG	GGT	GGT	TGG	CTC	AAA	GTC	AAC	GGT	TCA	TAC	TAC	TAC	TAC
	met	881	ACA	ACA	ACA	trp										
1861	/	621	ATG	AAA	GCA	AGC	CAA	TGG	TTC	AAA	GAT	GAT	TGG	TAC	TAT	TCT
	met	881	lys	lys	lys	ser	glu	lys								
1921	/	641	GCT	CTT	GCA	GTC	ACA	ACA	ACT	GTA	GAT	GGC	TAT	AAA	ATG	GGT
	lys															
1981	/	661	GCT	CTT	GAT	TAA	ATT	AAA	GCA	TGT	TAA	GAA	CAT	TTC	AAT	GAA
	lys	cys	lys													
2041	/	681	GAT	CTT	CGA	TTG	AAT	AGA	TTG	ATG	TTC	GTA	TTC	TTT	TAA	TGA
	lys															

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FIG. 4A. MATURE PsPA

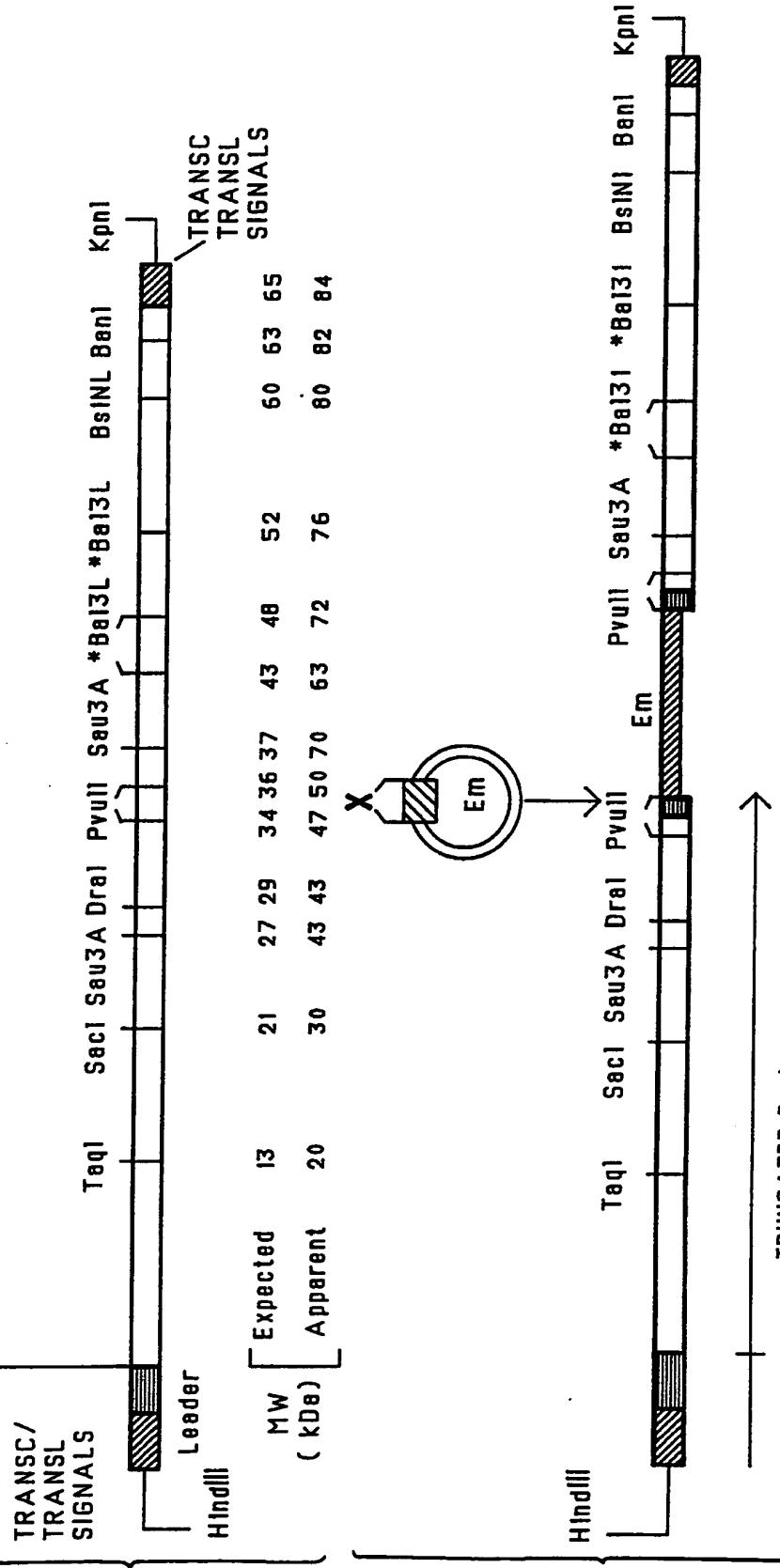


FIG. 4B.

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Location of epitopes detected by monoclonal antibodies to PspA

XI1526^{*}
 XI126^{*}
 XIR35
 XIR148
 XIR1224

XIR16

138 HHHHH

193 HHHHH

XI64^{*}
 XIR278^{*}
 XI1325^{*}

261 HHHHH

XI1323^{*}

	<i>a</i>	<i>b</i>	<i>c</i>	<i>d</i>	<i>e</i>	<i>f</i>	<i>g</i>
1	<i>E</i>	<i>E</i>	<i>s</i>	<i>p</i>	<i>y</i>	<i>a</i>	<i>s</i>
8	<i>Q</i>	<i>s</i>					
15	<i>y</i>	<i>D</i>	<i>K</i>	<i>a</i>	<i>E</i>	<i>K</i>	<i>D</i>
22	<i>a</i>	<i>K</i>	<i>N</i>	<i>a</i>	<i>K</i>	<i>K</i>	<i>D</i>
29	<i>y</i>	<i>E</i>	<i>D</i>	<i>a</i>	<i>K</i>	<i>K</i>	<i>a</i>
36	<i>L</i>	<i>D</i>	<i>D</i>	<i>a</i>	<i>K</i>	<i>D</i>	<i>K</i>
43	<i>Q</i>	<i>K</i>	<i>K</i>	<i>y</i>	<i>E</i>	<i>K</i>	<i>a</i>
50	<i>Q</i>	<i>K</i>	<i>K</i>	<i>E</i>	<i>D</i>	<i>K</i>	<i>a</i>
57	<i>a</i>	<i>a</i>	<i>L</i>	<i>E</i>	<i>D</i>	<i>Q</i>	<i>Q</i>
64	<i>s</i>	<i>E</i>	<i>E</i>	<i>L</i>	<i>Q</i>	<i>Q</i>	<i>K</i>
71	<i>y</i>	<i>a</i>	<i>a</i>	<i>a</i>			
78	<i>y</i>	<i>L</i>	<i>a</i>	<i>a</i>			
85	<i>t</i>	<i>D</i>	<i>K</i>	<i>a</i>			
92	<i>a</i>						
97	<i>L</i>	<i>D</i>	<i>E</i>	<i>a</i>	<i>D</i>	<i>K</i>	<i>R</i>
104	<i>E</i>	<i>E</i>	<i>E</i>	<i>a</i>	<i>K</i>	<i>R</i>	<i>K</i>
111	<i>L</i>	<i>N</i>	<i>a</i>	<i>E</i>	<i>R</i>	<i>K</i>	<i>Q</i>
118	<i>L</i>	<i>a</i>	<i>E</i>	<i>E</i>	<i>K</i>	<i>K</i>	<i>K</i>
125	<i>L</i>	<i>s</i>	<i>E</i>	<i>E</i>	<i>K</i>	<i>K</i>	<i>K</i>
132	<i>s</i>	<i>E</i>	<i>E</i>	<i>E</i>	<i>K</i>	<i>K</i>	<i>K</i>
139	<i>L</i>	<i>a</i>	<i>E</i>	<i>E</i>	<i>K</i>	<i>K</i>	<i>K</i>
146	<i>L</i>	<i>a</i>	<i>E</i>	<i>E</i>	<i>K</i>	<i>K</i>	<i>K</i>
153	<i>L</i>	<i>a</i>	<i>E</i>	<i>E</i>	<i>K</i>	<i>K</i>	<i>K</i>
160	<i>L</i>	<i>a</i>	<i>E</i>	<i>E</i>	<i>K</i>	<i>K</i>	<i>K</i>
167	<i>y</i>	<i>D</i>	<i>a</i>	<i>E</i>	<i>E</i>	<i>y</i>	<i>a</i>
174	<i>p</i>	<i>Q</i>	<i>a</i>				
178	<i>L</i>	<i>a</i>	<i>E</i>	<i>L</i>	<i>E</i>	<i>N</i>	<i>Q</i>
185	<i>L</i>	<i>H</i>	<i>E</i>	<i>E</i>	<i>D</i>	<i>E</i>	<i>S</i>
192	<i>L</i>	<i>K</i>	<i>E</i>	<i>E</i>	<i>E</i>	<i>D</i>	<i>y</i>
199	<i>E</i>						
204	<i>a</i>	<i>K</i>	<i>E</i>	<i>g</i>	<i>L</i>	<i>R</i>	<i>D</i>
211	<i>p</i>	<i>K</i>	<i>Q</i>	<i>g</i>	<i>K</i>	<i>L</i>	<i>s</i>
218	<i>a</i>	<i>K</i>	<i>K</i>	<i>g</i>	<i>K</i>	<i>L</i>	<i>D</i>
225	<i>K</i>						
226	<i>L</i>	<i>E</i>	<i>E</i>	<i>L</i>	<i>S</i>	<i>D</i>	<i>K</i>
233	<i>L</i>	<i>D</i>	<i>E</i>	<i>L</i>	<i>D</i>	<i>D</i>	<i>E</i>
240	<i>L</i>	<i>a</i>	<i>K</i>	<i>L</i>	<i>E</i>	<i>D</i>	<i>Q</i>
247	<i>L</i>	<i>K</i>	<i>a</i>	<i>L</i>	<i>E</i>	<i>D</i>	<i>N</i>
254	<i>L</i>	<i>N</i>	<i>N</i>	<i>y</i>	<i>E</i>	<i>D</i>	<i>y</i>
260	<i>t</i>	<i>K</i>	<i>E</i>	<i>g</i>	<i>L</i>	<i>E</i>	<i>K</i>
267	<i>t</i>	<i>L</i>	<i>a</i>	<i>g</i>	<i>K</i>	<i>K</i>	<i>a</i>
274	<i>E</i>						
275	<i>L</i>	<i>E</i>	<i>K</i>	<i>t</i>	<i>E</i>	<i>a</i>	<i>D</i>
282	<i>L</i>	<i>K</i>	<i>K</i>	<i>a</i>	<i>y</i>	<i>N</i>	<i>E</i>

FIG.5.

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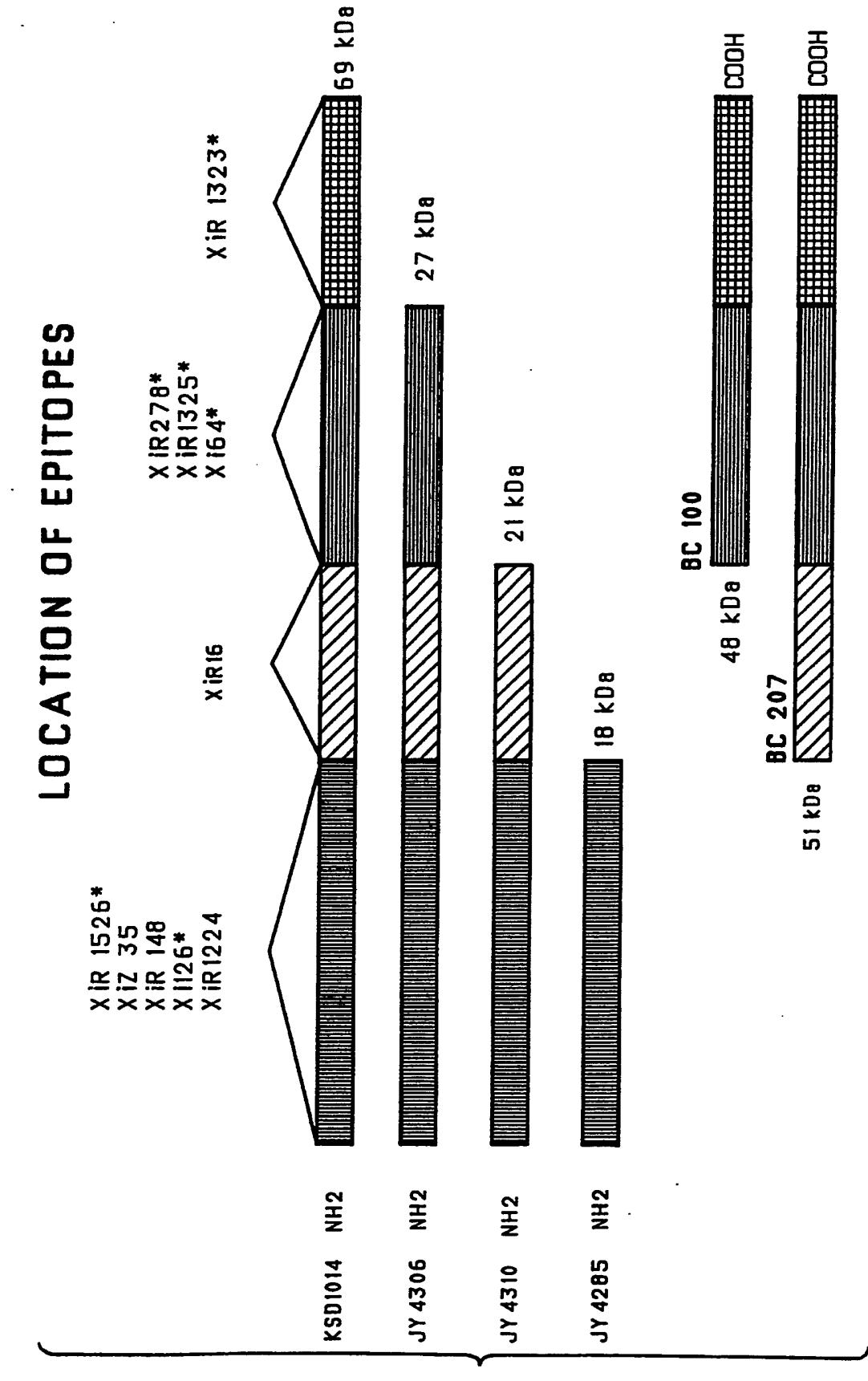
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	Xi 126	XiR 1224	XiR 148	XiR 1526	XiR 35	XiR 16	XiR 278	XiR 1325	XiR 64	XiR 1323
KSD 1014	++	++	++	++	++	++	++	++	++	++
JY 4306	++	++	++	++	++	++	++	++	++	++
JY 4310	+	+	++	++	++	+	-	-	-	-
JY 4285	++	+	++	++	++	+	-	-	-	-
KSD 1500	-	-	-	-	-	-	-	-	-	-
BC 100	-	-	-	-	-	-	++	++	++	++
BC 207	-	-	-	-	-	-	++	++	++	++

FIG.6.

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LOCATION OF EPITOYPES



SUBSTITUTE SHEET

FIG. 7.

INTERNATIONAL SEARCH REPORT

International Application No. PCT/US92/00857

I. CLASSIFICATION OF SUBJECT MATTER (If several classification symbols apply, indicate all) ³		
According to International Patent Classification (IPC) or to both National Classification and IPC		
IPC (5) : A61K 39/12; C12N 1/20; C07H 15/12, 13/00 US CL : 530/350; 536/27; 435/253.8, 253.1, 253.4; 424/89		
II. FIELDS SEARCHED		
Minimum Documentation Searched ⁴		
Classification System	Classification Symbols	
	530/350; 536/27; 435/253.8, 253.1, 253.4; 424/89	
Documentation Searched other than Minimum Documentation to the extent that such Documents are included in the Fields Searched ⁵		
U.S. Automated Patent System (File USPAT, 1971-1992), Dialog (file - Biochem)		
III. DOCUMENTS CONSIDERED TO BE RELEVANT¹⁴		
Category ⁶	Citation of Document ¹⁵ with indication, where appropriate, of the relevant passages ¹⁷	Relevant to Claim No. ¹⁸
Y	Abstracts of the 89th Annual Meeting of the ASM, 14-18 May 1989, McDaniel, et al., "Molecular Cloning of the Gene Encoding PspA (Pneumococcal Surface Protein A) and Analysis of Protective Immunity Induced by PspA. See Abstract No. D-255.	1-58
Y	Microbial Pathogenesis, Vol. 1, issued 1986, McDaniel, et al., "Analysis of a Surface Protein of Streptococcus pneumoniae recognized by Protective Monoclonal Antibodies", pages 519-531, see entire document.	1-58
Y	Journal of Experimental Medicine, Vol. 165 issued February 1987, McDaniel, et al., "Use of Insertional Inactivation to Facilitate Studies of Biological Properties of Pneumococcal Surface Protein A (PspA)", pages 381-394, see entire document.	1-58
<p>⁶ Special categories of cited documents:¹⁶</p> <p>"A" document defining the general state of the art which is not considered to be of particular relevance</p> <p>"E" earlier document but published on or after the international filing date</p> <p>"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)</p> <p>"O" document referring to an oral disclosure, use, exhibition or other means</p> <p>"P" document published prior to the international filing date but later than the priority date claimed</p> <p>"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention</p> <p>"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step</p> <p>"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art</p> <p>"&" document member of the same patent family</p>		
IV. CERTIFICATION		
Date of the Actual Completion of the International Search ² 18 MAY 1992	Date of Mailing of this International Search Report ² 04 JUN 1992	
International Searching Authority ¹ ISA/US	Signature of Authorized Officer ⁷  LYNETTE SMITH	

FURTHER INFORMATION CONTINUED FROM THE SECOND SHEET

V. OBSERVATIONS WHERE CERTAIN CLAIMS WERE FOUND UNSEARCHABLE¹

1. Claim numbers „, because they relate to subject matter (1) not required to be searched by this Authority, namely:

2. Claim numbers „, because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out (1), specifically:

3. Claim numbers „, because they are dependent claims not drafted in accordance with the second and third sentences of PCT Rule 5.4(a).

VI. OBSERVATIONS WHERE UNITY OF INVENTION IS LACKING²

This International Searching Authority found multiple inventions in this international application as follows:

Please See Attached Sheet.

1. As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims of the international application.

2. As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims of the international application for which fees were paid, specifically claims:

3. No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claim numbers:

4. As all searchable claims could be searched without effort justifying an additional fee, the International Search Authority did not invite payment of any additional fee.

Remark on protest:

The additional search fees were accompanied by applicant's protest.

No protest accompanied the payment of additional search fees.

FURTHER INFORMATION CONTINUED FROM PREVIOUS SHEETS

VI. OBSERVATIONS WHERE UNITY OF INVENTION WAS LACKING
This ISA found multiple inventions as follows:

- I. Claims 1-7, 16-23, 45-49 drawn to a first protein, method of making the protein and a method of using protein in a vaccine composition. Classes 530, 435, subclasses 350, 235.4 and 92.
- II. Claims 8-15 drawn to a second product - DNA. Class 536, subclass 27.
- III. Claims 24-35 drawn to a third product - mutant strain of *Streptococcus*. Class 435, subclass 253.4.
- IV. Claims 36-44 drawn to a second method of producing the mutant strain of bacteria. Class 435, subclass 252.3.
- V. Claims 50-57 drawn to a fourth product - DNA probes and DNA primer. Class 536, subclass 27.
- VI. Claim 58 drawn to a third method of assaying the protein. Class 435, subclass 7.1.
- The claims of groups I, II, III and V are drawn to different products. The claims of group I, IV and VI are drawn to different methods of either producing the protein or using the protein. The products and methods have reached a separate status in the art as evidenced by their different classifications. PCT Rules 13.1 and 13.2 do not provide for multiple distinct methods and products within a single inventive concept.

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- OTHER:** _____

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